1.1 Average Speed

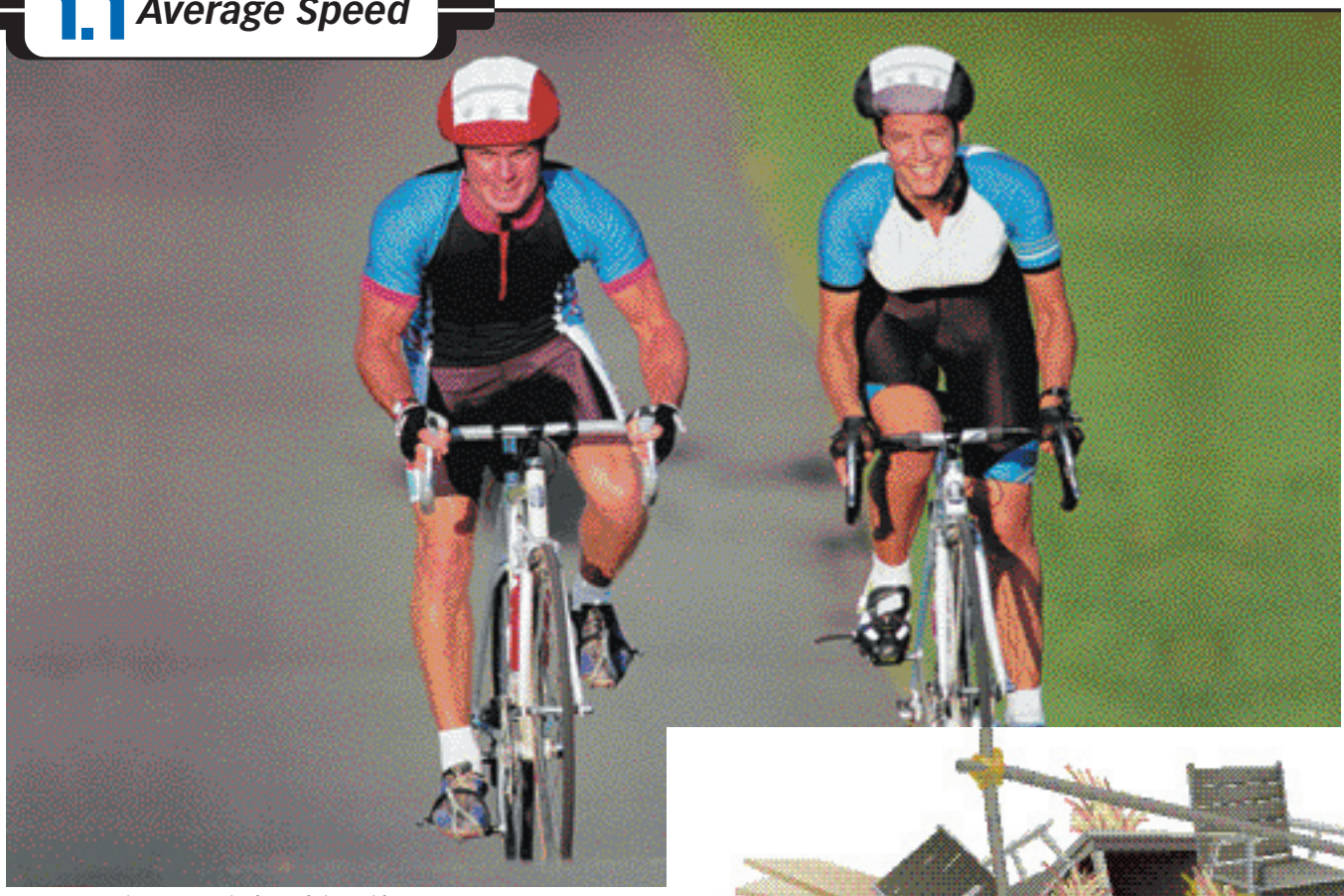


Figure B1.3: Cycling is a popular form of physical fitness.

If you ask these cyclists where they are going, they might say, "We're going to a homestead near Warburg. It's about two-and-a-half hours from Leduc." A driver of a car passing these cyclists might describe Warburg as being only a half-hour away. How can the village of Warburg be described so differently?

Pioneer Travel

In 1907, this same journey took an early pioneer named John Anderson about ten hours by oxcart. At that time, this part of Alberta was covered by boreal forest and the only route was a rough trail carved through the woods, swamps, and streams. This is why Anderson took so much longer to cover the same distance.

Historical Travel

If you went back in time even further, prior to the arrival of European settlers to Alberta, a group of lightly equipped Sakawinowak (Woodland Cree) hunters might have been able to travel this same route on foot, through the dense forest, in about nine hours.

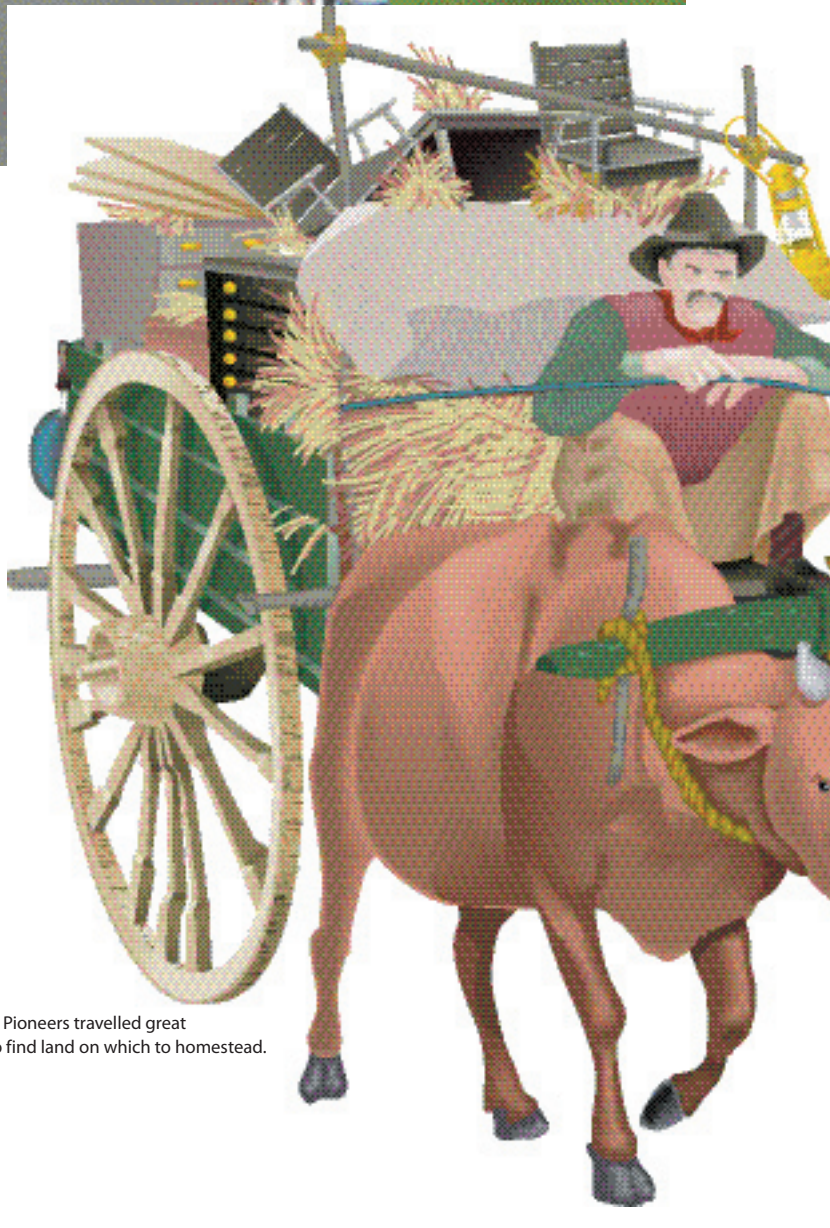


Figure B1.4: Pioneers travelled great distances to find land on which to homestead.

Average Speed

In each mode of transportation, the distance travelled is the same, but the times for the various means of motion are different. This is due to differences in **average speed**. Average speed is equal to the total distance travelled divided by the elapsed time.

$$\text{average speed} = \frac{\text{total distance}}{\text{elapsed time}}$$

$$v = \frac{\Delta d}{\Delta t}$$

average speed: the distance travelled over a specified time

Figure B1.5 illustrates the effect of average speed on the elapsed time.

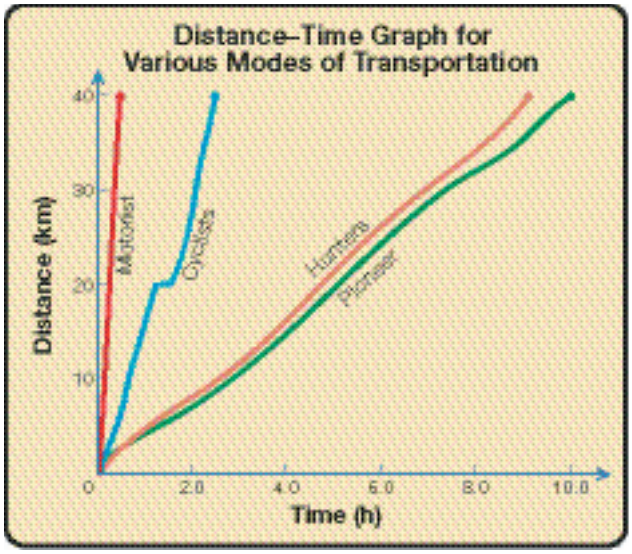
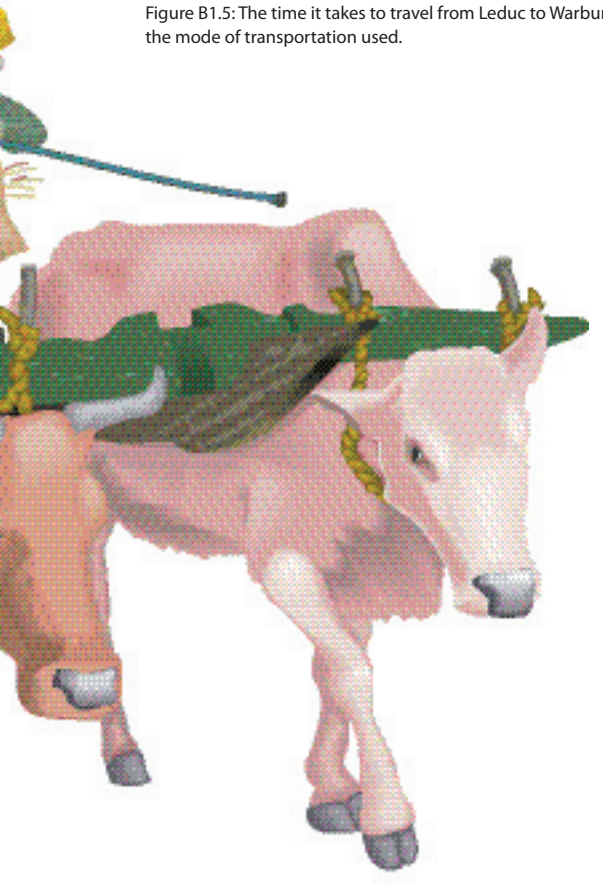


Figure B1.5: The time it takes to travel from Leduc to Warburg depends on the mode of transportation used.



Example Problem 1.1

Use the endpoint of the graph of the cyclists to determine their average speed.

Solution

$\Delta d = 40 \text{ km}$

$\Delta t = 2.5 \text{ h}$

$v = ?$

$$v = \frac{\Delta d}{\Delta t}$$

$$= \frac{40 \text{ km}}{2.5 \text{ h}}$$

$$= 16 \text{ km/h}$$

The cyclists' average speed was 16 km/h.

Practice

Use the information presented in Figure B1.5 to answer questions 1 to 3.

1. Determine the average speed of the
   a. motorist
   b. pioneer
   c. hunters
2. a. During the trip, did the cyclists stop and rest?
   b. If the cyclists stopped for an additional 30 min, determine their resulting average speed.
3. Who completed the journey with a constant speed?

Uniform Motion

Figure B1.5 shows that each mode of transportation covered the same distance but with different elapsed times. The graph also shows other details about the trip. Notice that the car, likely on cruise control, is the only one that produced a straight line. On the sections of the highway that were straight—sections where the car was travelling in a straight line—the car was moving with **uniform motion**.

uniform motion: motion in a straight line at a constant speed

Non-uniform Motion

N**on-uniform motion** is illustrated by the other modes of transportation in Figure B1.5. They show changes in speed, direction, or both.

In the natural world, uniform motion is rare. In most cases, an object speeds up, slows down, or turns. The result is non-uniform motion.

non-uniform motion: motion with a change in speed, direction, or both

Practice

4. Which of the objects in Figure B1.6 shows non-uniform motion? Explain your answer.

Figure B1.6: From left to right, you see ivy growing, an eagle fishing, and Angel Glacier at Jasper National Park.

Instantaneous Speed

Although rare in the natural world, humans have created technologies that can move with uniform motion. A car on cruise control travelling on a straight, level section of highway is a good example. The signs posted along the highway remind drivers of the maximum speed they are allowed to travel without breaking the law. Speed limits are set for daylight driving under ideal conditions. Drivers are expected to reduce their speeds when conditions aren't ideal. It is also important to note that these speed limits do not refer to the maximum average speed of the vehicle; they refer to the maximum **instantaneous speed**.

instantaneous speed: speed at an instant of time

Scalar Quantity

Drivers receiving a speeding ticket might argue that they were travelling under the posted speed limit for most of their trip. However, that fact doesn't matter if the particular moment they exceeded the speed limit was the same time their speed was monitored.

A speed limit sign identifies the maximum speed permitted at any moment along a roadway, but it does not show which way you are travelling. When you think about it, the road determines your direction because you are following it! Since the speed printed on the sign does not contain any information about direction, it is an example of a **scalar quantity**.

scalar quantity: a quantity consisting of magnitude only, not direction

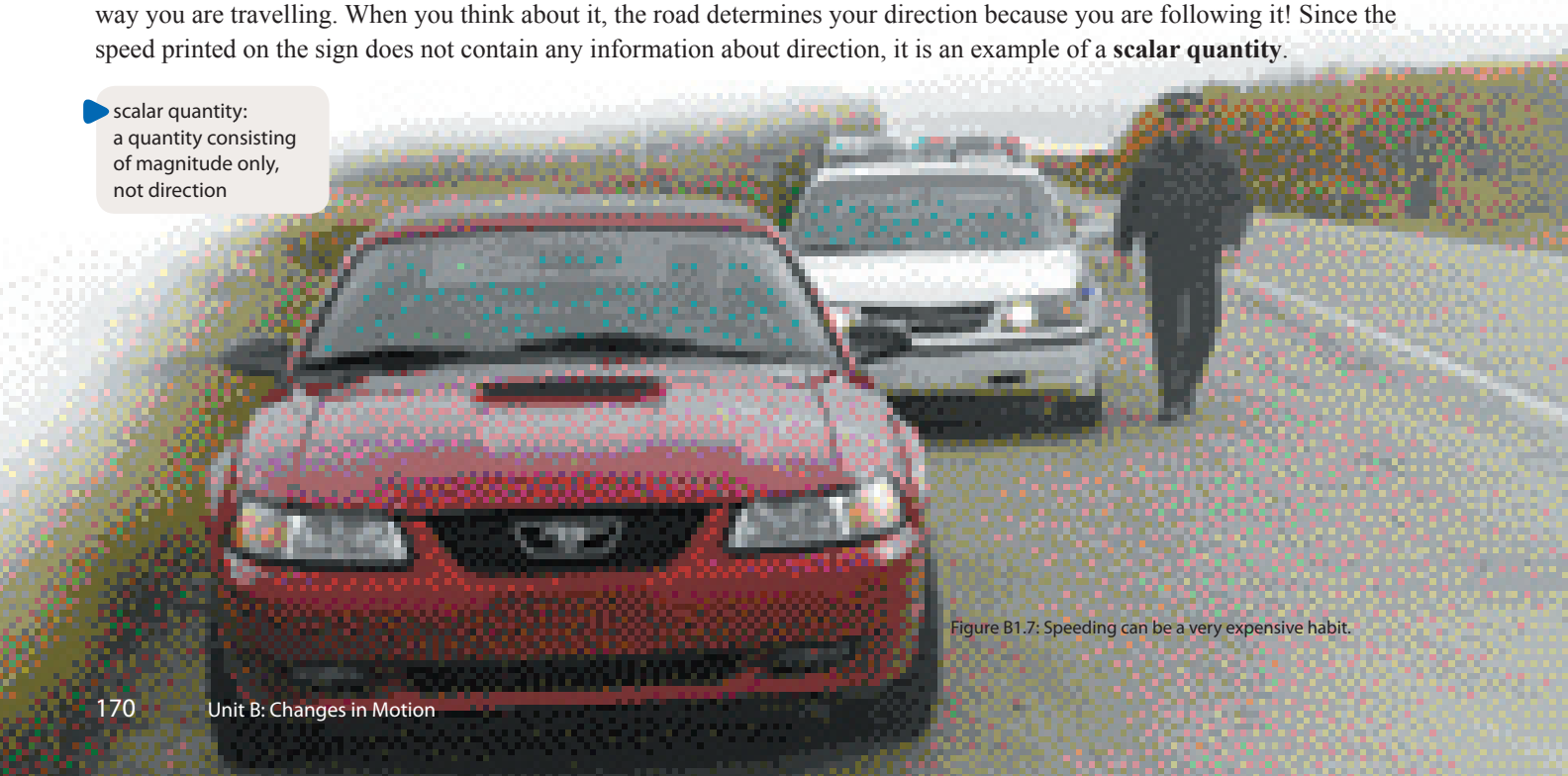


Figure B1.7: Speeding can be a very expensive habit.

Scalars

Highway signs are not the only place where scalar quantities appear. They are also frequently found on packages of consumer goods because people want to know how much is in the packages. You will also see scalar quantities used to describe elapsed time, volume, or any other measurement that does not include direction.

Practice

5. Closely examine the following items.

a. Which items illustrate scalar quantities? Explain.
b. Some of the items do not show scalars. What do these items all have in common?
c. Write four statements that contain a scalar quantity.

Conversion Factors

Notice that highway signs that display scalar quantities often don't include units. Since there is a limit on the amount of information that a driver can safely read from a sign while driving, not to mention a limit on the size of the sign, highway signs often leave out details like units. So, it is understood among drivers in Canada, unless otherwise stated, that highway signs always give distances in kilometres and speeds in kilometres per hour (km/h).

Example Problem 1.2 illustrates how conversion factors can be used to help sort out different units while problem solving.

Example Problem 1.2

An owl is able to drop 1.30 m in 0.80 s to capture its prey. Determine the owl's average speed during its descent in metres per second and kilometres per hour.

Figure B1.8: An owl pounces on its prey.

Solution

$\Delta d = 1.30$ m, $\Delta t = 0.80$ s, $v = ?$

Determine the average speed in metres per second.

$$v = \frac{\Delta d}{\Delta t}$$
$$= \frac{1.30 \text{ m}}{0.80 \text{ s}}$$
$$= 1.625 \text{ m/s}$$
$$= 1.6 \text{ m/s}$$

Convert the average speed into kilometres per hour.

$$v = 1.625 \frac{\text{m}}{\text{s}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{3600 \text{ s}}{1 \text{ h}}$$
$$= 5.85 \text{ km/h}$$
$$= 5.9 \text{ km/h}$$

¨ **Remember:** When using a value from a previous calculation, always use the unrounded value for a more accurate calculation.

The average speed of the owl during its descent is 1.6 m/s or 5.9 km/h.

Did you notice how the answers in Example Problem 1.2 were rounded to two significant digits? Recall the rules of significant digits. In this case, although the distance measurement has three significant digits, time has only two significant digits. Therefore, the answer must be rounded to two significant digits. For additional information regarding significant digits and rounding, read "Calculations with Significant Digits" on pages 534 to 536. Try keeping all these things in mind as you do the Practice questions.

Practice

6. David drives his quad 20.5 km into the back country to get to his favourite lake to fish for trout. If it takes 2.5 h to get to the lake, determine David's average speed in kilometres per hour and metres per second.
7. The sound waves from a thunderclap can travel 20.6 km in 1.0 min. Determine the speed of sound in metres per second.
8. During a track meet, Kelsey ran the 80-m hurdles event in 12.2 s. Determine Kelsey's average speed in metres per second and kilometres per hour.

1.1 Summary

Uniform motion is movement at a constant speed in a straight line. In the natural world, uniform motion is rare because most motion is non-uniform. Average speed and instantaneous speed are useful quantities when describing motion. As the names imply, average speed is an average calculated over an interval of time, whereas instantaneous speed is the speed at an instant of time. Both are examples of scalar quantities—they have magnitude but no direction. Speed calculations often require converting units, which can be conveniently done using a conversion factor.

1.1 Questions

Knowledge

1. Define each of the following terms.

- **a.** uniform motion
- **b.** non-uniform motion
- **c.** instantaneous speed
- **d.** scalar quantity
- **e.** conversion factor

2. Use one or more conversion factors to convert each of the following measurements into seconds.

a. 90.0 min **b.** 30 days **c.** 17 years

3. Use a conversion factor to convert each of the following measurements into metres.

a. 628 µm **b.** 1.3 mm **c.** 85.5 cm **d.** 285 km

Applying Concepts

4. You are a passenger travelling in a car where the driver has engaged the cruise control, maintaining a constant speed of 90 km/h. You are moving on a straight section of level highway.

- **a.** State the type of motion demonstrated by the car.
- **b.** Suppose you glance at the speedometer every few seconds. What scalar quantity does the speedometer display? Would you expect the reading of the speedometer to change during this part of the trip? Explain.
- **c.** Unknown to both you and the driver, a small plane flying over your section of the highway was measuring the time it took your vehicle to travel between two painted stripes on the pavement 250 m apart. If an RCMP officer in the aircraft determined the time to be 10.0 s, calculate the average speed of the car in kilometres per hour.
- **d.** What can you conclude about the values for average speed and instantaneous speed when an object is travelling with uniform motion?

Figure B1.9: On some occasions, police have monitored traffic from low-flying aircraft.